Enterprise Risk Management
Professor Paul Sweeting

Lecture 1 – Introduction to ERM

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What is ERM?

- Holistic management of risk in an enterprise…
- …where an enterprise can be
  - Firm
  - Society
  - Charity
  - Pension Fund
  - Etc…

Not just risk management?

- Important additional concept:
  holistic approach
- Means considering all risks
  - Consistently
  - Together
- Relatively easy for quantitative risks…
  …but principle still true for qualitative ones
- Important to recognise distinction between quantitative/qualitative

Why manage risk?

- Better risk/return trade-off
- Better capital efficiency
  - Financing costs
  - Project choice
- Increased attractiveness to customers
  - Target credit rating
- Avoid regulatory interference (and regulators require risk management…)

Implications of ERM

- Holistic approach, as discussed
- ERM suggests a formalised approach to risk management
- Suggests presence of central risk function
- Implies integration of risk management into normal business practice

Advantages of ERM

- Diversifying effect of risks recognised…
  …as are concentrations
- Central responsibility for all risks means less chance risks will be missed…
- …and risks can be prioritised
- Integration of ERM into business means organisations constantly considering risk

Types of risk

- Need to define risk types
  - Rewarded
  - Unrewarded
- Rewarded risk
  - Premium paid for risk taken
  - E.g. equity investment
- Unrewarded risk
  - Can remove without reducing expected return
  - E.g. inadequate back-office procedures

Rewarded and unrewarded risk

- Distinction not always clear
- Investment
  - Often a premium (e.g. equities)…
  - …but not always (e.g. long bonds for short liabilities)
- Insurance
  - Expense…
  - …but might be worth it

Rewarded and unrewarded risk

- Improved operational systems
  - Reduce operational risk…
  - …but not free
  - Weigh cost against potential loss…
  - …similar principle to underwriting
- Diversifiable risk
  - Probably the clearest cut...
  - ...unless particular reason undiversified risk taken

Risk vs uncertainty

- Uncertainty – don’t know the outcome
- Risk – implies adverse outcomes
- Implications for risk measurement
  - Volatility not necessarily important…
  - …since includes favourable outcomes
  - Downside risk measures more relevant

What is a risk framework?

- ERM requires holistic management of risk...
- ...and risk frameworks are systems for this
- Broad structure within which risk treated
- Three types of framework are of interest
  - Proprietary
  - Mandatory
  - Advisory

Proprietary risk framework

- Implemented by firms
- Good examples are credit rating agency approaches
  - AM Best
  - Fitch Ratings
  - Moody’s
  - Moody’s KMV
  - Standard & Poor’s

Credit ratings

- Issuer rating
  - Overall financial strength of issuer
- Issue rating
  - Financial strength in relation to particular issues
  - Collateral, seniority, term, options etc
- Insurer financial strength rating
  - Ability to meet obligations to policyholders
- Bank deposit rating
  - Ability to meet obligation to depositors
- Bank financial strength rating
  - Likelihood that bank will require external support.
- Ratings may differ for single institution...
- ...but approach consistent within agency

Mandatory risk framework

- Imposed by regulatory authorities
- Most relevant here are financial ones
  - Basel II
  - Solvency I/II (Europe)
- Assess risk on a number of levels

Basel II

- Designed to promote stability in banking sector
- Published by Basel Committee on Banking Supervision (BCBS)...
- ...which was set up following evident lack of cross-border co-ordination in early 1970s
- Based on 3 pillars
  - Minimum capital requirements
  - Supervisory review process
  - Market discipline

Basel II – pillar 1

- Capital Adequacy
- Three areas
  - Market risk
  - Credit risk
  - Operational risk
- Three tiers of capital that can be used
- Risks combined into single number
- Required level of solvency is 99.5% one-year VaR (Value at Risk)

Basel II – pillar 2

- Supervisory review
- Recognises holding capital not enough...
- ...although review might mean requirement to hold more capital
- Various aspects
  - Requirement for internal process in firms (forms basis for review by regulator)
  - Regulator to ensure operation above minimum level
  - Verify operational risk approach consistent with business

Basel II – pillar 3

- Market discipline
- Essentially promotion of transparency
- Requirement for firms to publish
  - Details of risks
  - Details of capital
  - Details of ways in which risk managed
- Aim is to encourage good risk management...
- ...to lower risk-weighted cost of capital

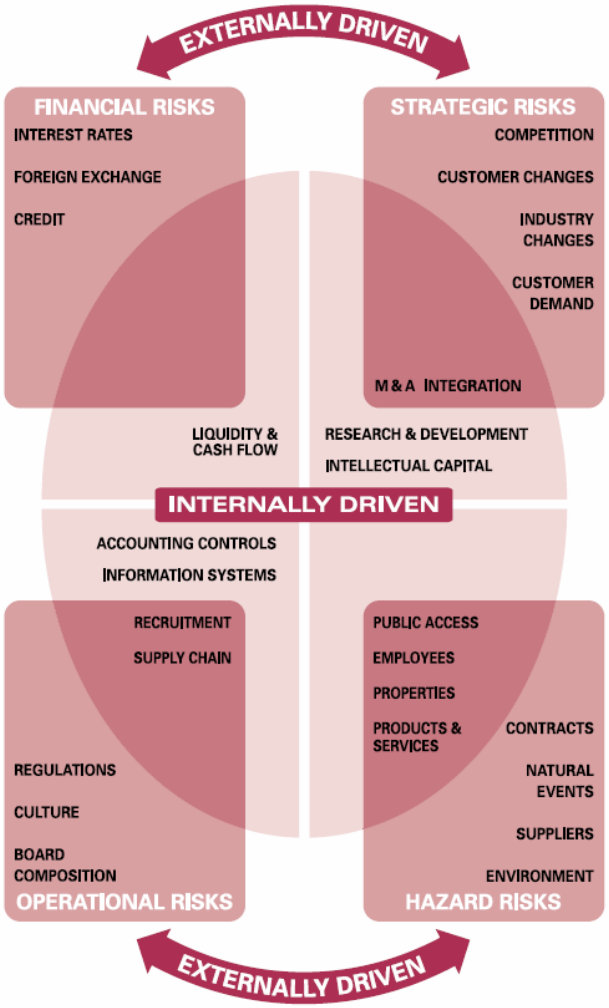
Basel II – issues

- Risk as single number – hides detail (less informative than Basel I, since more risks?)
- Liquidity (currently) given limited treatment
- Spurious levels of confidence
- Increasing complexity confused with confidence
- Marking to market causes pro-cyclicality
- Failure to deal with systemic risks
- Added complications increase expense

Advisory risk framework

- Aimed at helping organisations of all sorts control risk
- Many examples
  - COSO ERM Integrated Framework
  - IRM/AIRMIC/ALARM Risk Management Standard
  - Orange Book
  - AS/NZS 4360: 2004
  - BS 31100
  - ISO 31000
  - Etc...

IRM/AIRMIC/ALARM – Framework



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IRM/AIRMIC/ALARM – Process

Stages of ERM

- Determine context
- Determine risk appetite
- Identify risks
- Quantify risks
- Compare with level of risk with risk appetite
- Determine response to risk
- *All the time monitoring and reporting*

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Lecture 2 – Copulas

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What is a copula?

- A copula is a formula...
- ...defining the joint distribution...
- ...of two or more variables...
- ...in terms of their distribution functions
- Copulas work in terms of the distribution functions of the variables...
- ...not the underlying variables

Sklar's theorem

- If F(x) is the probability that X≤x...
- ...and F(y) is the probability that Y≤y...
- ...and F(x,y) is the probability that X≤x and Y≤y...
- ...then

$$C(F(x),F(y))=F(x,y)$$

- C(F(x),F(y)) is a copula function
- Furthermore, if x and y are continuous...
- ...then this copula is unique

Important points to note

- The copula is not affected by the shape of the marginal distribution...
- ...since it is defined by the *position* of each observation...
- ...not its *value*
- This means that new measures of association are needed that are determined only by the rankings of observations

Rank correlation coefficients

- Spearman's rho:

$$1-\frac{6\sum\left(V_i-W_i\right)^2}{N\left(N^2-1\right)}$$

- Kendall's tau:

$$\frac{2\left(p_c-p_d\right)}{N\left(N-1\right)}$$

Example:

- An insurance company has the following total claim values from two portfolios, X and Y over a five year period, with claims X_t and Y_t in each year t
- Calculate Spearman's rho and Kendall's tau

t	X_t	Y_t
1	10	20
2	95	25
3	15	10
4	35	15
5	45	30

Spearman's rho

- V is the rank of X, W is the rank of Y...
- ...so rho = $1 - 6 \times 8 / (5 \times (5^2-1)) = 0.6$

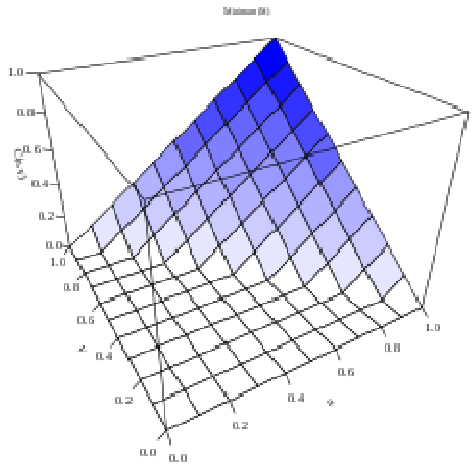
t	X_t	Y_t	V_t	W_t	V_t-W_t	$(V_t-W_t)^2$
1	10	20	5	3	2	4
2	95	25	1	2	-1	1
3	15	10	4	5	-1	1
4	35	15	3	4	-1	1
5	45	30	2	1	1	1
Total						8

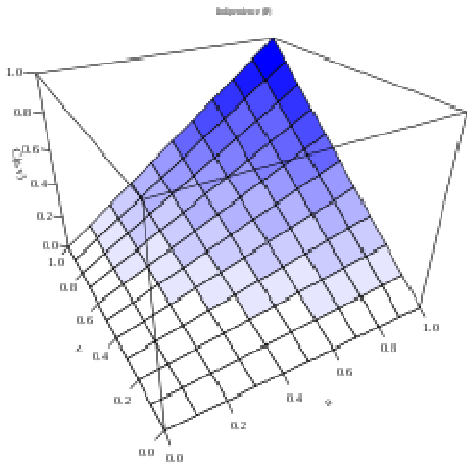
Kendall's tau

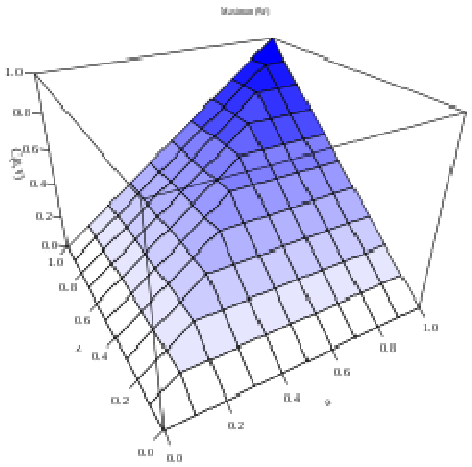
- 7 concordant pairs...
- ...3 discordant pairs...
- ...so tau = 2 x (7-3) / (5 x (5-1)) = 0.4

t	X_t	Y_t	vs t=1	vs t=2	vs t=3	vs t=4
1	10	20				
2	95	25	C			
3	15	10	D	C		
4	35	15	D	C	C	
5	45	30	C	D	C	C

Fréchet Copulas







Archimedean copulas

- Class of copulas...
- ...that directly links distribution functions...
- ...using a generator function, ψ...
- ...and a (pseudo)-inverse, $\psi^{[-1]}$
- Generator function converts a number ranging from 0 to 1...
- ...to a number ranging from 0 to ∞
- Inverse does the reverse
- If the generator function has a finite maximum, a pseudo-inverse is needed

How Archimedean copulas work

- Process:
  - Take the individual cumulative probabilities (0→1)
  - Apply the generator function to each (0→∞)
  - Sum the results (0→∞)
  - Apply the pseudo inverse to the total (0→1)
  - The result is the cumulative joint probability
- This demonstrates why a pseudo-inverse is needed...
- ...since if the sum of the generated results is greater than the maximum value from a generator function...
- ...a strict inverse would not a 0<p<1

Archimedean copulas and correlation

- Often simple links between copula parameters and rank correlation coefficients
- E.g Kendall's tau:
  - Gumbel: $\tau = 1 - (1/\alpha)$
  - Clayton: $\tau = \alpha/(2+\alpha)$
- This makes parameterisation easy...
- ...but means limited degree of dependency can be modelled for large number of variables

Example Archimedean copula

- Two insurance claims, X and Y
- P(X≤£50,000) = 0.873, P(Y≤£30,000) = 0.922
- Claims linked by a Gumbel copula with α=2.5
- What is P(X≤£50,000 and Y≤£30,000)?
- Gumbel Generator is $\psi(F) = (-\ln F)^{\alpha}$.
- $\psi(F(x)) = (-\ln 0.873)^{2.5} = 0.00680$
- $\psi(F(y)) = (-\ln 0.922)^{2.5} = 0.00188$.
- Inverse is $\psi^{-1}(G) = \exp[-(\Sigma G)/\alpha]$
- C(F(x), F(y)) = exp[−(0.00680+0.00188)/2.5...
- ...= 0.861

Gaussian copula

- $C(F(x),F(y))=\Phi_R[\Phi^{-1}(F(x),\Phi^{-1}(F(y))]$
- Translate two (or more) probabilities into standard normal variables
- Take these standard normal variables as inputs for a multivariate normal distribution...
- ...defined only by a correlation matrix...
- ...and calculate the joint cumulative probability
- Wider range of dependencies...
- ...but may underestimate joint extreme events
- Using Student's t-copula instead can help

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Lecture 3 – Case Studies

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Good and bad risk management

- Helpful to have examples of good risk management...
- ...but rarely hear when disasters averted...
- ...so case studies based on risk management failures
- Books written about most failures...
- ...so limited coverage here...
- ...but you should read more if interested

Case Studies

- The collapse of Barings Bank
- Long-Term Capital Management
- The Madoff investment scandal
- The Space Shuttle Challenger disaster
- Korean Air

Barings – background

- Trader Nick Leeson supposed to be arbitraging between Nikkei 225 futures listed in Osaka and Singapore...
- ...but took directional bet on Nikkei 225...
- ...but made losses, which he tried to hide in a dummy account...
- ...and falsified trading records...
- ...but ran out of time when the Kobe earthquake occurred

Barings – organisational short-comings

- What caused the losses?
  - Poor trading strategy?
  - Kobe earthquake?
- No – operational failures
  - Leeson head of trading and head of settlement...
  - ...so in a position to fraudulently account for trades
  - Good internal controls would have prevented the fraud...
  - ...so prevented the collapse

Long-Term Capital Management – background*

- US hedge fund
- Included 2 Nobel laureates on the board
- Used fixed income arbitrage between Government bonds...
- ...plus high leverage to enhance profits
- Started with off-/on-the-run US Treasuries...
- ...then expanded to inter-market trades

**from "The Quants" by Scott Patterson*

Collapse of LTCM

- 1997 Asian financial crisis, 1998 Russian financial crisis caused flight from European, Japan to US Treasuries...
- ...so prices diverged rather than converging...
- ...meaning LTCM became insolvent

LTCM – excessive trust

- Financial crises?
- No – excessive trust
  - Trust by LTCM in its models – failure to recognise that models only represent reality, do not replicate it...
  - ...and in this case, underestimated small risk of very large movements in wrong direction
  - Trust by investors in LTCM – Nobel laureates on board, so they must know what they're doing...

Madoff Investment scandal – background

- Investment manager for charities, trusts, high net worth clients
- Provided high, stable returns to clients...
- ...but returns the result of a Ponzi or pyramid scheme
- Payments to existing investors made from new subscriptions
- When uncovered, many investors bankrupted

Madoff Investment scandal – collusion and vanity

- Fraud on the part of Madoff?
- Partly...but how did it happen?
- Feeling of exclusivity
  - Invited to join – felt like a privilege – playing on people's vanity
- Insufficient auditing
  - Long-standing auditor relationship...
  - ...with personal friend (conflicted?)...
  - ...with a very small practice (lack of skill?)...
  - ...which was itself breaking laws
- Collusion a major factor...
- ...which is difficult to guard against

Space Shuttle Challenger – background*

- Space Shuttle broke apart 73 seconds after take-off
- A rubber seal in a booster rocket failed...
- ...allowing hot gasses to escape and explode...
- ...causing the Shuttle to break up
- Rogers Commission set up to investigate failure

**from "What do You Care What Other People Think" by Richard Feynman*

Space Shuttle Challenger – organisational failure

- Clearly the o-ring failure was key...
- ...but it was only the final failure
- Many more organisational failures preceded this
  - Problems with o-ring known about for years...
  - ...but concerns not raised with NASA management
  - Engineer concerns not recognised by management
  - Management misunderstanding of risk measures (failure rate, risk of failure etc)
  - Cultural problems allowed failure to happen
- Many lessons here for financial risk management

Korean Air – background*

- Up to 1999, the loss rate of Korean Air was 4.79 aircraft per million departures...
- ...whereas for United Airlines, it was 0.27
- Audit of operations found many failings
  - Crew smoking on tarmac during refuelling
  - Crew reading newspapers during flight, obscuring warning lights
  - Poor morale, procedural violations, poor training
- However, these were symptoms, not causes

**from "Outliers" by Malcolm Gladwell*

Korean Air – cultural issues

- Korean was the language used in the cockpit...
- ...so communication with Air Traffic Control harder (global aviation language is English)...
- ...but also built in cultural attitudes to authority...
- ...including reluctance to challenge superiors (in cockpit and in Air Traffic Control
- Solution? English now the working language of Korean Air – makes it easier to challenge decisions made in the cockpit
- No accidents since 1999...
- ...and Korean Air now part of SkyTeam Alliance

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Extra Slides – The Risk Management Context

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Determining the context

- External context
  - External stakeholders
  - Political environment
  - Economic environment
  - Social and cultural environment
  - Competitive environment
  - Regulatory environment
  - Professional environment
  - Industry environment
- Internal context
  - Internal stakeholders
  - Organisational culture
  - Organisational structure
  - Capabilities

Financial institutions

- Banks
- Insurance companies
- Pension schemes
- Endowments/foundations

Banks

- Current full-service banks relatively new
- Historically, many types
  - Private
  - Mutual
  - High Street
  - Investment
  - Merchant
  - Commercial

Differences between banks

- Ownership structure
- Customers
- Products
- Business model

Insurance companies

- Life – varying term...
  - Short tail (e.g. annual group life)
  - Long tail (e.g. annuities)
- ...and varying payout
  - Non-profit (e.g. annuities)
  - With-profit (e.g. endowment policies)
- Non-life – wide range of policies
  - Long tail (e.g. employer liability)
  - Short tail (e.g. car insurance)

Pension schemes

- Defined benefit and defined contributions
- Funded and unfunded
- Occupational pension schemes established under trust law
  - Contributions paid by employer
  - Asset and liabilities responsibility of trustees
- Personal pensions run under contract law
  - Direct relationship between insurer and individual

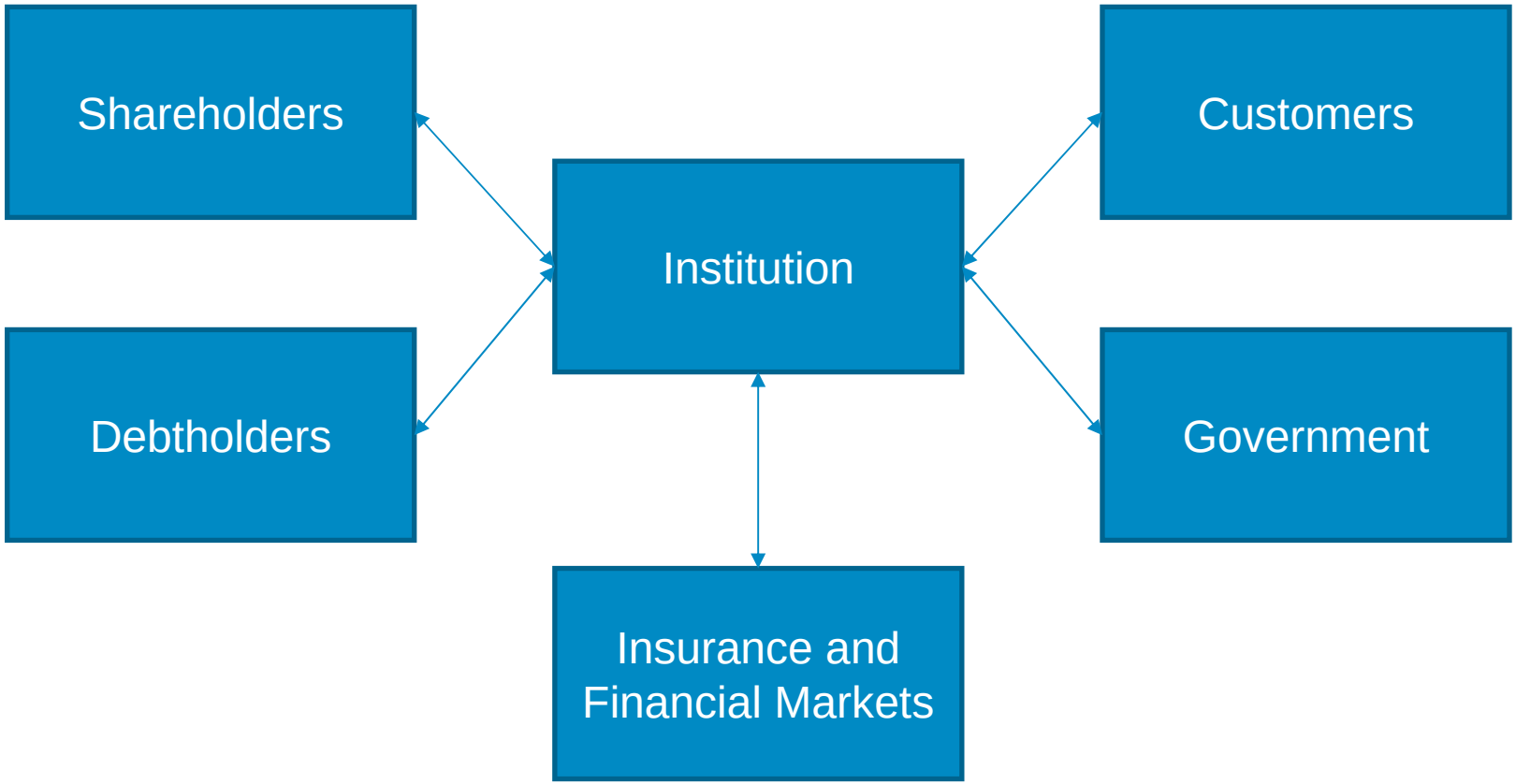
Endowments/foundations

- (Usually) charitable organisations
- Provide funds for many reasons
  - Hospitals
  - Universities
  - Medical research
- Endowment – funded by single payment
- Foundation – receiving ongoing funding

Views of risk

- Various potential relationships with institutions
- Can categorise as
  - Principal
  - Agency
  - Controlling
  - Advisory
  - Incidental

Principal relationships



List of principals

- Public and private shareholders
- Holders of public and private debt
- Bank customers
- Insurance company policyholders
- Pension scheme sponsors
- Pension scheme members
- Endowment/foundation beneficiaries
- Government (financial relationships)
- Statutory insurance schemes
- Financial markets

Agents

- Agents are individuals or groups that act on behalf of someone or something else...
- ...in theory
- Instinct of agents is to act for themselves...
- ...not for the principal
- Gives rise to the principal-agent problem

Principal-agent problem

- Potentially present whenever anyone acts for anyone else
- Financial burden is agency cost
- Two methods of control
  - Restrictions (“stick”)
  - Incentives (“carrot”)
- Disclosure can itself be an incentive
- Important concept: cost of control should be less than agency cost

List of agents

- Company directors
- Trustees
- Company managers & employees
- Trade unions
- Central risk functions
- Pricing teams
- Auditors
- Pension scheme administrators
- Investment managers

Controlling

- Also parties who do not act for principals...
- ...but influence their (and agents') actions
- Role should be to limit excessive risk
- Full list
  - Professional bodies
  - Professional regulators
  - Industry bodies
  - Industry regulators
  - Government (controlling)

Advisors

- No control...
- ...but significant influence
- Full list
  - Actuarial
  - Investment and finance
  - Legal
  - Credit

Incidental relationships

- Parties affected incidentally by behaviour of financial institutions
  - trade creditors and debtors
  - subcontractors and suppliers
  - general public
  - the media